Pers Ubiquit Comput (2015) 19:1233–1245
DOI 10.1007/s00779-015-0889-1

ORIGINAL ARTICLE

Empirically derived user attributes for the design of home healthcare technologies

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Received: 6 August 2015 / Accepted: 17 November 2015 / Published online: 6 December 2015

Abstract Designing effective home healthcare technologies is a complex task. In order to succeed, it is important to look beyond purely technology-driven solutions and to develop technologies and services that are flexible and reflect a sensitive understanding of the diverse users of such systems. The key contribution of this paper is to introduce 15 empirically derived attributes that can help designers to build a more detailed understanding of the potential users of home healthcare systems. The attributes are spread across four broad themes: technology in the home, experiences of technology, experiences of health and care, and thoughts about smart home technology for health and care. These themes and attributes emerged from an ethnographic study in which we interviewed people across 15 households. All interviews took place in people's homes and were supplemented by home technology tours and cultural probes. It is intended that the 15 attributes be used in conjunction with demographic and household data to build a richer picture of personal experiences of home, health, and technology in real-life contexts. The aim was to provide an inclusive framework, based on empirically derived attributes, that helps to inform an overall user-centred design approach. To demonstrate one application of the attributes in design, the paper provides in-depth example of their use in the development of a rich set of data-driven personas.

Keywords Smart home · Healthcare · User-centred design · Ethnography · User attributes · Personas

1 Introduction

In many home healthcare technology systems, the aim is to monitor and support individuals, through a combination of networked home sensors, data processing, and interactive feedback, in order to track health indicators and enable people to live a more healthy life while remaining in their homes. However, although technologies underlying pervasive and ubiquitous computing have advanced rapidly [1] and research in smart homes has shown much promise [5], many challenges remain. Hardisty et al. [14] argue that more than two decades of work in the field of telemonitoring has yet to produce successful implementation of clinically relevant systems that support management of long-term health conditions. This failure is attributed to insufficient understanding both of stakeholders' needs and of the complex dynamics within healthcare service models. In order to develop home healthcare technologies that can support a broad range of health conditions, they recommend a user-centred and platform-oriented approach that sees technology as a basis around which a range of capabilities and services can be integrated.

Achieving this goal will require ongoing technological innovation, but also requires sensitive understanding of the potential users of such systems. Consideration must be given to a wide range of people, throughout different life

Electronic supplementary material The online version of this article (doi:10.1007/s00779-015-0889-1) contains supplementary material, which is available to authorized users.

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stages and with differing experiences of health and illness. It is crucial to understand how individuals differ as users of technology and also how they differ as patients and in their experience of health services. Taking the perspective that experiences are constructed through embodied interaction [15], it is important to situate this understanding in the home context. Homes are complex and dynamic spaces, which hold personal meanings for their occupants. These spaces are often shared by several individuals whose differences in terms of socio-demographic characteristics, abilities, and attitudinal variables such as self-efficacy beliefs and computer anxiety will influence their acceptance, and use of technology [7].

The key contribution of this paper is to introduce 15 empirically derived attributes that can help designers to build a more detailed understanding of the potential users of home healthcare systems. The aim is to provide an inclusive framework, based on empirically derived attributes, that helps to inform an overall user-centred design approach. The attributes, which are grouped across four themes, emerged from an ethnographic study in which we interviewed people across 15 households. This study and the inductive derivation of themes and attributes are discussed in Sect. 3. Section 4 provides an in-depth discussion of how the attributes, together with our ethnographic data, were used to develop a rich set of data-driven personas. We begin with a more detailed consideration of recent research investigating the design of smart home technology to support health care.

2 Related work

In recent years, non-clinical smart home technologies have begun to make their way out of the laboratory and into homes. This has provided valuable lessons into people's lived experiences of these technologies. For example, research on the deployment home automation systems by Brush et al. [4] identified four barriers to a wider adoption of home automation, which are the high cost of ownership, inflexibility, poor manageability, and difficulty achieving security. Other research highlighted aspects of user experience, namely the importance of designing meaningful technologies, of recognising the complexity of domestic spaces, and of facilitating human–home collaboration [19]. Customisable approaches to smart home development have been proposed in order to provide a better fit between diverse end-users and home automation in general [4, 18, 19], as well as for healthcare purposes [14]. This is in line with a call to abandon a vision of smart technologies that anticipate the needs of their users, in favour of an empowered user who engages with technology to manage their everyday lives [6, 24].

A study that looked at people's experiences of creating a smart home found that children become more easily accustomed to the technology while guests may struggle with technology that is unfamiliar to them [18]. The same study also identified three roles of household members regarding their smart homes, which reflected how people planned, iterated, and used these technologies. These roles were: *home technology drivers* who actively engaged in planning and were primarily responsible for the technology when it had been installed; *home technology responsibles* who did not engage directly with the technology, but were responsible for having it installed and would contract professionals to repair or adjust the technology when necessary; and *passive users* who did not engage with any phase of the home automation, but had some familiarity with the system through use. A determining difference between these roles was having a technical background, with most of the study participants falling into the category of passive users.

Adding the healthcare dimension to domestic technologies creates further layers of complexity. Di Blasi et al. [8] report that health outcomes are determined by multiple factors, including the effect of context. Context comprises five types of factors: the characteristics of the treatment, the characteristics of the patient, the characteristics of the practitioner, the relationship between the practitioner and the patient, and the healthcare setting. Of particular relevance to the aims of this paper are the patient's characteristics, which include their physical reaction to the treatment, behavioural response (e.g. adherence and lifestyle changes), cognitive response (e.g. beliefs about their illness and expectations about cure or management), and emotional response (e.g. fear, anxiety, and denial). Our aim in this paper is to extend these findings and to explore user experience of home healthcare technology from a broader perspective. We consider not just "patients" who are already experiencing health conditions and related treatments, but also people who are healthy, but whose attitudes and behaviour in relation to health and perceptions of technology may impact on their future health and attitudes towards home healthcare technologies. This is in line with a call for assisted living technologies that are customisable to individual users and their changing needs, including the ability to share information and track changes over time [26].

We recognise that user experience results from the interplay of several factors, some of which are ascribed to the product or service, others to the user, and others still to the context of the interaction [9]. People influence their own experience through their emotions, values, abilities, and previous experiences, but products or services and their users are also part of a wider social, cultural, and organisational context of use, which also shapes how individual experiences are formed. This fits well with current perspectives on the role of patients in preventing and

managing long-term illness, which have shifted from the self-management approach of conventional medicine, through an approach focused on coping with illness, and finally the whole systems approach that is prevalent today [12]. A whole systems approach sees patients, healthcare professionals, and the wider community working together to develop holistic and personalised care plans. In this scenario, innovations must seek to inform and empower the patient to actively engage in the management of their well-being. This change also corresponds to a change in healthcare service design. It has been observed that as the healthcare service philosophy progressed from disease-centred to patient-centred and then to patient-led, the design focus shifted accordingly from service efficiency to interaction and then to behavioural change [10]. Service design is concerned with the creation of engaging user experiences across multiple touchpoints, as this creates value for its customers [22]. Through our ethnographic study, we aim to identify the touchpoints and patient attributes that inform peoples' experiences of and attitudes to home healthcare technology.

3 Ethnography study

The aim of this study was to explore people's current technology and healthcare-related behaviours in real-life contexts, in accordance with the first phase of UCD [16]. Specifically, we focused on the individual, their home and community, and the reciprocal effect of these contexts on their technology and healthcare practices. This research was carried out as part of the user-centred design activity of the SPHERE project. SPHERE (Sensor Platform for HEalthcare in a Residential Environment) is an interdisciplinary research collaboration, which aims to address a range of healthcare needs through data fusion and pattern recognition from a single platform of non-medical networked sensors in the home environment [27]. These sensors comprise a range of environmental sensors, RGB-D cameras, as well as wearable devices powered through energy harvesting and transfer.

As we were interested in informing the development of healthcare technology for domestic use, we conducted our research with people in their own homes. Rich qualitative data were gathered using ethnographic methods, which aimed to empower participants in the data collection process. The ethnographic study was provided with research ethics approval by the University of Bristol's Faculty of Engineering Human Research and Ethics Committee.

3.1 Recruitment and participants

Potential participants were approached through public engagement activities and through project community partners, namely the Knowle West Media Centre and Bristol City Careline. The sample was not intended to be statistically representative, but was a purposive sample designed to ensure a balanced inclusion of households with prior experience of telecare and smart energy sensors, together with households with no reported experience of telecare or smart home technologies. The households approached during recruitment included some with prior experience of telecare systems (comprising at least a personal wrist-worn or pendant alarm and pull-cord alarms throughout the home, linked to a base unit) and some who had previously participated in an evaluation of home sensing technologies that monitored energy usage but not health. Whenever possible, we involved all residents in each household.

In total, 19 participants across 15 households took part in the study. Tables 1 and 2 summarise the households and participants, respectively. Participant ages ranged from 19 to 77, with a median age of 51. Participants included people who reported living with no health conditions, as well as people with single and multiple diagnosed health conditions such as long-term pain and cancer.

Table 1 Summary of households

House occupancy	Number
Living alone (one occupant)	5
Living with partner (two occupants)	5
Living with child (two occupants)	2
Living with housemate (two occupants)	1
Living with partner and children (three or more occupants)	2

Experience of technology	Number	Housing status	
Experience of telecare	4	Own house or flat	6
Experience of home sensors	4	Privately rented	2
Other	7	Local authority	5
		Sheltered housing (with resident warden)	2

Table 2 Summary of participants

Gender			Number
Male			8
Female			11
Education	Number	Employment status	
Master's degree	2	Full time	7
Bachelor's degree	8	Part time	1
A level or similar	3	Unemployed	3
GCSE or similar	2	Retired	8
No formal qualifications	4		
Long-term health conditions		Employment status	
No diagnosed health conditions	7	Informal caregiver for an older relative living elsewhere	4
Single long-term health condition	7	No caregiving responsibilities	15
Multiple long-term health conditions	5		

3.2 Data collection

Data collection comprised several elements. First, we conducted semi-structured interviews and technology tours of homes. In the semi-structured interviews, participants were asked to talk about their feelings and attitudes towards their home, their experiences with technology, and health from their own perspective or as informal carers. These interviews took place over one or more home visits. To further explore participants' interrelationships with their environments, we asked them to conduct tours of their homes to discuss the technology present in each room. This is an established technique in HCI, with variations including the Technology Tour [21] and the Technology Biography [2]. This type of walking tour allows artefacts and spaces to serve as prompts for conversation, while also enabling the researcher to get a sense of the material and immaterial elements that form individual homes [20]. Participants were thus encouraged to share rich stories about the technology they owned and its role within the home. Similarly, when talking about health, participants were asked to relate their experiences to their home and contemplate how circumstances might change in the future.

Second, cultural probes were used to enable participants to reflect on their health and homes. This is a method pioneered by Gaver et al. [11], which we adapted to suit the purpose of this study. Our probe kits contained three elements. First, the Map of Me allowed participants to show on a body outline what health conditions they have and what technology they carry or wear, by using different coloured stickers. Second, the Map of My Day was a daily timeline that invited participants to record their activities and what technologies they had used, then to reflect on how their experiences could have been improved. Finally we included a digital camera with ten prompts to elicit photos. We intended these probes to be open-ended, and we encouraged participants to express themselves however they preferred. We conducted a further interview with each participant, after the probes had been completed and returned. At these interviews, participants were asked to talk about the examples and experiences they had shared through the cultural probes.

When other data collected were complete, we conducted a focus group in the prototype SPHERE home. This provided an opportunity for participants to see and critique the first version of the multi-modality sensor platform, but also to suggest features that would be of interest to them.

All participants took part in interviews; responses to the cultural probes varied, with 10 participants returning completed elements of the packs. All participants were invited to attend the focus group in the SPHERE house, and five were able to attend.

3.3 Data analysis

Interviews were audio-recorded and transcribed in full. Material collected through cultural probes was returned to the research team and included photographs, completed body maps and maps of daily activities. These data were inductively coded using a thematic approach to analysis [3]. Two authors independently read a sample of the interview transcripts, assigned inductive codes to the data, and grouped these codes into categories. The code lists of each researcher were compared, and a coding scheme was agreed. The rest of the data set was then coded, and the coding scheme was refined, as data collection and analysis progressed.

3.4 Findings

Our thematic analysis identified four key themes: technology in the home, experiences of technology, experiences of health and care, and thoughts about smart home technology for health and care. We will discuss each of these themes in turn. As we do so, we also highlight key differentiating attributes that emerged across our participants.

3.4.1 Technology in the home

Participants had a varying *amount of technology in their home*. All households had major domestic appliances, such as refrigerators and washing machines, and all had televisions. Ownership and use of information and communication technologies (ICT) were most varied, ranging from one household that had no computer or similar device to households that owned multiple computers. Three households did not have Internet connection when the study began, although one of these had broadband installed during the course of data collection.

During the Technology Tours, it was interesting to observe that people had different attitudes towards the *visibility of technology in their home*. Some participants were keen for technology not to be a noticeable feature of their homes, often keeping it inside cupboards and drawers when not in use. One participant explained how this concern could even influence her decisions of what technology to buy.

> **Interviewer:** I see that you have things quite tucked away, not prominent. The technology isn't very prominent in the room.
> **Julie:** No [laughs], I'm not going to be having an enormous screen on my chimney breast or anything. No, I don't want it to dominate and, in fact, one of the reasons I would go for a newer TV is that – I would still end up with a little tiny one, the kind of things that most people would put in their caravans or in their kitchens maybe – I quite like the idea of having a flat screen because then I would fold it back and I would put it in that corner over there, actually, and tuck it under so you wouldn't see it at all [laughs].

Keeping technology concealed was described as not always possible, and most participants had at least some technology visible in their homes. The following participant, who liked to have his technology on display, talked about how it is a matter of getting used to seeing the technology, as happens with other artefacts around the home. This extract was taken from a conversation about how the participant might feel about having SPHERE technology in the home.

> **Interviewer:** And how do you feel about having things on show? You said perhaps a camera there – would it bother you to see it?
> **Jerry:** No. It's like all the rest of things – you put something up on the wall like that [picture] there, for the first three weeks I probably looked at that every day, now I have to think about it. Technology or anything put in the room, for the first couple of weeks you see it every day, then you see it once a week, and after a bit you don't see it at all.

3.4.2 Experiences of technology

Participants reported different *frequency of use of ICT*. Although 11 participants reported using some form of ICT several times a day, some participants hardly ever or never used ICT. One participant had no experience using computers or similar technology. When given the digital camera as part of the cultural probes, she was nervous about using it and remained uncertain after the researcher had showed her how it worked. Another participant explained that he did not read or write well, and that meant that he was not able to use ICT easily. Nevertheless, most participants had some experience of using ICT and over half reported using them several times a day.

It was evident from the data that people had different *roles in technology use*, and these roles could vary depending on the type of technology. Participants who used telecare had either moved into accommodation such as sheltered housing that was already fitted with telecare systems, or adoption of these systems had been driven by their children. Looking more broadly at technology in the home, only three of the participants with experience of telecare were passive users, one fitted the category of technology driver, and one corresponded to a technology responsible. In fact, most participants (nine) were in this middle ground between passive users and drivers. The following quote is taken from a participant who enjoyed playing computer games on various devices, several times a day.

> **Interviewer:** And how do you download games onto your tablet?
> **Brenda:** I don't. My son does it. My son takes it home for me when I want games put on it. I say to him on the Friday 'Take that home and put something on there for me'.
> **Interviewer:** So he knows what you like?
> **Brenda:** Yes, he buys a lot of my [Nintendo] DS games for me. He knows the sort that I like. Yes, he's always saying to me "Mum, you've got so and so amount of money [left]", I say "Why?" Once he said "I've just bought you a DS", I said "No, you've got

me a DS and I've got to pay for it". So I said "Yes, alright". Yes, he bought a load of the DS games for me.

We also found variation in people's *previous experiences of smart or healthcare technologies*. Although participants who had home sensors for energy monitoring made some negative comments related to the appearance of the sensors in the home, feelings were overall positive. The main reasons given for this were that through having the sensors they had learned how to be more energy efficient and had therefore reduced their energy bills. For one participant, these benefits were not sufficient to keep using the system, as illustrated by her justification for removing them from her home.

Laura: I'd learnt a lot and I don't think there was anything more that I could have learned by carrying on with [it]. I don't think there is any point.

Participants with experience of telecare were mostly positive about these technologies. However, one participant living in sheltered accommodation felt the system had serious limitations, which he illustrated with an example:

Interviewer: Have you ever had to use it?
Jerry: Once. Once, I found myself passing out and I hit the button [on the personal alarm]. And that's when I found out it couldn't know where I was, because I actually passed out in the garden. I hit the button and I could hear them shouting for me [through the base station inside the flat] – right, wonderful. Because there's no speakers or anything in the garden either, so if you're in the garden you're nowhere near an alarm system that can pick your voice up. The box in the hallway can actually hear you anywhere in the flat, no matter where you are. So, it can talk to you wherever you are in the flat, which is nice.

Telecare users reported often not wearing their personal alarms because they were uncomfortable, they were not adequate (e.g. did not work outside the home), or they interfered with daily activities. The following excerpt is taken from a conversation with a participant who kept her pendant alarm hanging on a shelf.

Linda: We were out one night, and the point was the cat pressed the thing. The emergency [call] came and they couldn't get any reply. They had to come and see if I was all right or not. I wasn't in. I pressed it and told them that I was all right and that it was the cat what done it.

3.4.3 *Experiences of health and care*

Our multi-methods approach revealed that people sometimes described themselves as "healthy" when asked about their *self-perception of health*, although they lived with one or more *health conditions.* For instance, some participants described themselves as healthy in interview and subsequently shared various examples of health conditions on their body maps. In further discussion, it often transpired that having health conditions did not necessarily mean that people considered themselves ill or in need of care. This was particularly the case when those health conditions did not affect daily life. Figure 1 shows some examples of completed body maps, in which yellow stickers indicate

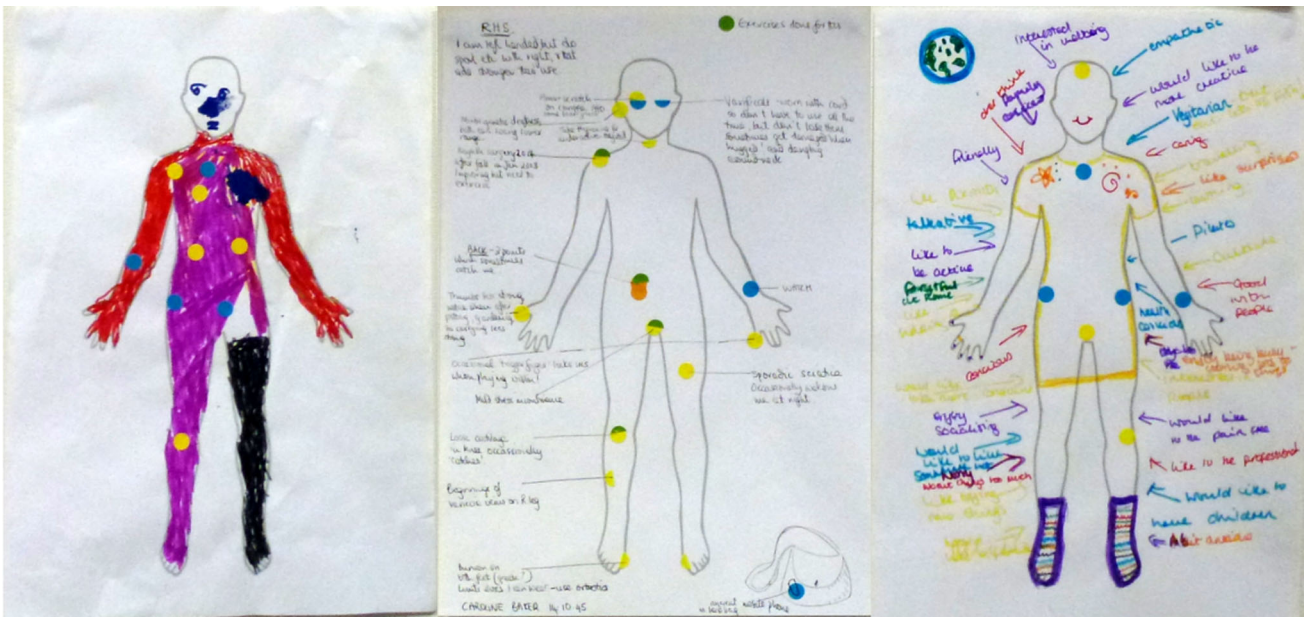

Fig. 1 Examples of body maps, completed by three different participants

health conditions and blue stickers indicate technology that participants wear or carry with them.

The study found diverse perspectives on *health information-seeking behaviour*, as well as *care-seeking behaviour*. Attitudes towards understanding health conditions ranged from no active seeking of information to using multiple methods to understand health conditions, including keeping food diaries, reading medical books, and searching online. Not seeking care was rare, but some examples were shared of participants or someone in their household resisting until someone else made them do it. In some instances, this attitude was echoed in their *adherence to medical advice*. Non-adherence was sometimes clearly described. For example, Dave, aged 51, explained how he went against medical advice to stay in bed due to a back injury, and returned to his two manual labour jobs within a couple of days. These resistant attitudes were caused by fear, stoicism, not perceiving a treatment as effective, and not wanting to inconvenience themselves or others.

Participants also discussed their *experiences of healthcare* services, in particular how negative experiences could have a lasting negative impact. One participant described a recent bad experience with her healthcare provider due to medication conflict, which she felt would put her off seeking medical advice in the future:

> **Claire:** Yeah, my last experience with the doctor I am not going on any medication. I've got no faith to even know that I went to the hospital with the medication that they put me on and all they told me was, "You've got flu. Go and buy some stuff over the counter and get on with it". I've got no faith in the hospital at all or the doctors.
> **Interviewer:** Was it because they weren't familiar with your medical history?
> **Claire:** I walked in. I said to them, "I've been feeling unwell. I've just been put on new migraine tablets and new blood pressure tablets". I took the tablets with me and she said, "You've got flu. Go and buy some stuff over the counter". And they left me like that for a fortnight. It was only when I actually managed to get an appointment with my main doctor and he went, "Who put you on blood pressure tablets?" I said, "The locum doctor when I came down here and my blood pressure was up due to me having a migraine". He said, "He didn't ask you to come back the next day and do a second reading?" I said, "No. He told me to go straight onto these blood pressure tablets". He said, "Every day you've been taking that blood pressure tablets it's been poisoning you. It's given you asthma and flu-like symptoms. You've now damaged your larynx so bad it's just going to take time", which is why I'm still a bit hoarse now because it's just going to take time to repair. He said, "You've been taking them for nearly a fortnight. I'm glad you've come into see my now because I don't know what would have happened and how long you would have been on those tablets".

3.4.4 *Thoughts about smart home technology for health and care*

Overall, participants were positive about the benefits of smart home technology for healthcare. Their *expectation that healthcare technology will provide benefit to others* tended to be greater than their *expectation that healthcare technology will provide benefit to self*. Even participants who fell into the category of older users (conventionally people over 65 years old) and who are the target of many research and development projects felt that this type of system was not relevant to them, but would suit "*older* older people" or people who had severe health conditions. Participants who had higher expectations of benefits were interested in gaining a better understanding of their health conditions, as illustrated by the following extract from an interview with a person who had back pain since she was a teenager.

> **Lisa:** I don't know whether that would help me. It would be interesting from a research point of view to see if it would help, do you know what I mean? That would be something that I would go "Yeah, absolutely. You can fit me with whatever to see if I do something that's odd – that makes it go, hang on a minute, this is affecting your whatever", but I don't know whether it would help me.

When asked about their *interest in seeing personal data* and their *interest in seeing household data*, feelings varied. Participants who had used smart home systems that helped them regulate their energy consumption were especially interested in their household data. Recalling the benefits they had experienced previously, some participants wondered if having access to household information might allow them to save money or if they could use this information to support claims against the local authority regarding their living conditions.

Many participants were not interested in viewing their personal data. One participant described how regular use of a blood pressure monitor left her with mixed feelings towards accessing health data.

> **Interviewer:** But are you personally interested in the values that you get and how they relate to each other, or is it just for the doctor to have a look at?
> **Rose:** Oh no, I'm interested as well. Yes, I like to…I've got mixed feelings about it – when I take my

blood pressure and I get a good result I feel chuffed, but if it's high it stresses me out even more. So it depends whether the news is good or bad. Yeah, so definitely a love-hate relationship there.

Regardless of feelings towards visualising personal and household data, the participants felt it was crucial that they had access to it and had primary control of it. After seeing the data dashboard in the prototype smart home, the focus group reflected on the implications that visualising personal and household data might have for them.

Jerry: For me, I'm dying of cancer. For all my good looks and vitality, I'm obviously dying of cancer. And if I had that graph, I'd see it going downhill.
Margaret: I think that at first I'd say I'm not interested, but I think I would want access to the information.
George: If you want to you can go and look for it…
Margaret: If I want to I can go and look at it.
Interviewer: What would it do if you had access?
Margaret: At this stage, with a scientific background, I am quite interested. Like your little monitor [tablet with sensor data dashboard] just showing me that I'm active – not terribly complex, but so I felt I had as much as you had. I mean, that I had all the information available somehow. If I was interested or like a child would say, "Are you sure it's okay that they're looking at this?" And if I couldn't quite understand, they could understand. So I don't think I'd look at it very much.
George: I might once a year. Looking at my electricity consumption might be quite handy [laughs]. Or gas or something, but that's rare.
Margaret: And I expect I'd get to know it, what it was doing.

3.5 Discussion

A key aim of this paper was to derive a comprehensive range of attributes across which people vary in their attitudes towards and experiences of health and technology in a home context. Overall our analysis of the ethnographic data identified four overarching themes, which contained a total of 15 user attributes. These themes and attributes are summarised in Table 3. The attributes listed in Table 3 are not binary, rather each reflects a continuum. For example, in the case of attribute 1 "amount of technology in the home" a person may lie somewhere on a continuum between none and a lot. A suggested continuum for each attribute is given in Table 3.

It is important to clarify what we mean by attributes and where we believe the attributes listed in Table 3 will be useful. Previous research on home healthcare technology and smart homes has emphasised that user diversity should be a key consideration in design [4, 7, 19]. It has also identified specific ways in which people may differ in their attitudes towards and interactions with technology. For example, researchers have identified three distinctive roles that people may adapt towards technology in the home [18]. We sought to extend this work. Rather than focus on a

Table 3 User attributes with suggested continua

Technology in the home	
1. Amount of technology in the home	None ↔ a lot
2. Visibility of technology in the home	All hidden ↔ all visible
Experiences of technology	
3. Frequency of use of ICT	Never ↔ often
4. Role in technology use	Passive user ↔ driver
5. Previous experience of smart/healthcare technology	Very bad ↔ very good
Experiences of health and care	
6. Health conditions	None ↔ severe
7. Self-perception of health	Very ill ↔ very healthy
8. Health information-seeking behaviour	None ↔ enthusiastic
9. Care-seeking behaviour	None ↔ enthusiastic
10. Experience of health care	Very bad ↔ very good
11. Reported adherence to medical advice	Non-adherent ↔ adherent
Thoughts about smart home technology for health and care	
12. Expectation that healthcare technology will provide benefit to self	None ↔ very high
13. Expectation that healthcare technology will provide benefit to others	None ↔ very high
14. Interest in seeing personal data	None ↔ very high
15. Interest in seeing household data	None ↔ very high

specific characteristic or role, the attributes in Table 3 consider a broad range of ways in which people may differ. In some cases, the attributes closely mirror the concerns identified in prior research. Through considering each of these attributes in turn, across a range of potential end-users, it is hoped that designers can build a richer picture of diverse experiences of home, health, and technology. This may help in designing new technologies that cater to this diversity. It may also prove useful in understanding how technology can be customised to different users, by identifying the attributes that best describe the interests or motivations of distinct users. For example, some people may be highly motivated by seeing personal data (attribute 14), whereas others may be interested in household data (attribute 15).

Each of the attributes in Table 3 has implications for the adoption of smart home systems, and each provides some standalone value in thinking about end-users. For example, attribute 4 focuses on a person's role in the use of technology in the home. In considering this attribute, the prior work of Mennicken and Huang [18] provides excellent insight. However, we believe the additional value lies in considering users in a comprehensive manner across the full range of attributes. This provides a more holistic framework, based on empirically derived attributes, that is sensitive to many distinct interests, motivations, and characteristics of diverse users.

To demonstrate one way in which these attributes can be applied as part of an overall user-centred design approach, the next section of the paper considers their use of the development of rich user personas.

4 Personas for designing smart home technologies for health and care

As previously mentioned, the ethnographic study described in this paper was undertaken as part of a large interdisciplinary project, SPHERE, which focuses on the development of new smart home technologies. Alongside gathering and interpreting our ethnographic data, one of the key challenges for the user-centred design team within SPHERE is to communicate these data in meaningful way to the broader team of approximately 40 hardware and

Fig. 2 Participants mapped to attributes

software research engineers. One of the ways in which we achieve this is through the use of personas. In user-centred design, personas are archetypal representations of real users that transcend demographic profiles or market segments. They are intended to convey rich behavioural data to support user-centred decision-making [23].

A comprehensive overview of the use of personas, in particular to support design of medical outputs, is provided in [25]. Those authors note the difficulty they experienced in reconciling divergent evidence when creating their own set of evidence-based personas. Another limitation of using personas is that their development can be a time-consuming process, especially in the absence of user models [17]. We see the existence of conflicting data as a natural outcome of diverse attitudes and behaviours among users. Our way to mitigate this challenge was to follow a rigorous persona development process described in [13], which facilitates a cross-case analysis, together with the 15 attributes identified in our ethnographic study. This approach provided a framework in which to develop a diverse set of evidence-based personas.

4.1 Development of the personas

We began our persona development process by expressing each attribute in Table 3 as continua between contrasting pairs. We then used different coloured sticky notes to represent the three types of participant: pink for households with telecare, green for households with experience of sensor technology, and yellow for other households. We wrote the pseudonym of each participant on the appropriate coloured sticky note and placed them along the continua for each attribute, based on the data gathered in the ethnography study. We recorded additional data of interest on individual sticky notes, using different coloured marker pens; for example, a blue circle was added to show who lived alone and a red circle was added to show who carers were. This mapping process, illustrated in Fig. 2, allowed participants' attributes to be visualised in relation to each other. Using this visualisation, we then looked for patterns, where two or more people occurred together on at least a third of the continua. We were also interested in obvious outliers, as they could represent a separate persona.

Fig. 3 Example persona of Rick Fletcher, containing his demographic details, a description of his experiences with technology and health, and his thoughts about using smart home technology for health and well-being

Through this process, we identified four meaningful patterns and one outlier, which we used to create skeleton personas. Referring back to the data, we assigned personal characteristics and developed a narrative for each persona. The emphasis was on creating believable characters, so we selected realistic photographs, names, and demographic data. The main purpose of these personas was to communicate evidence-based insights about people's different experiences and behaviours related to technology and health, with a view to informing the design of future healthcare systems and services. Accordingly, each persona comprised a description of their experiences with technology and health. Persona sheets also contained information on how the persona felt about smart home technology for health and care. Each persona was derived from the 15 attributes and a summary of their main motivations and perceived barriers to using smart home technology for health and well-being. Figure 3 shows one full persona. The full set of personas is available as supplementary material: Online Resource 1 is the persona of Rick Fletcher; Online Resource 2 is the persona of Wendy Brennan; Online Resource 3 is the persona of Stanley Chase; Online Resource 4 is the persona of Maxine Hadley; and Online Resource 5 is the persona of Oliver Adams.

Table 4 Summary of personas

Rick Fletcher	*Motivation to use smart home technology for health and well-being*
53 years old	Learning how to be more energy efficient
Lives with dyslexia	Saving money on utility bills
	Knowing what his daughter gets up to while he is at work
	Barriers to using smart home technology for health and well-being
	Not being able to read information from the system
	Fear that the system will detect a long-term or terminal condition that would prevent him from working
Wendy Brennan	*Motivation to use smart home technology for health and well-being*
64 years old	Feeling safe at home
Lives with multiple long-term health conditions	Using data as evidence to expedite the care she will need as her health deteriorates
	Not having to interact with the technology
	Barriers to using smart home technology for health and well-being
	Not keen to have cameras in her home, because she would feel watched
	Concerns about her privacy, especially because she feels she does not understand much about technology
Stanley Chase	*Motivation to use smart home technology for health and well-being*
38 years old	Learning about his long-term pain
Lives with long-term pain	Having a system that will notify someone of extreme pain events
	Knowing that his children are safe in the home
	Barriers to using smart home technology for health and well-being
	Not perceiving any benefits
	Technology that does not work well and just adds another disruption to his family life
Maxine Hadley	*Motivation to use smart home technology for health and well-being*
74 years old	Contributing to research that will benefit other people
Feels healthy and active	Keeping an open mind about how her circumstances might change in future
	Barriers to using smart home technology for health and well-being
	Feeling her home is dominated by technology
	Reluctance to believe that technology can ever replace the human element of healthcare services and well-being
Oliver Adams	*Motivation to use smart home technology for health and well-being*
31 years old	Learning about his health and fitness
Informal carer	Having a way to keep an eye on a frail relative that lives elsewhere
	Barriers to using smart home technology for health and well-being
	Not having control over the technology and the data that is collected
	Technology that does not integrate with the technology he currently uses

Table 4 provides a short summary of the motivations and barriers regarding the use of smart home technology for each persona.

4.2 Using the personas

We believe the five personas presented in this paper, and the process applied in their development, may prove useful for other designers of home healthcare technologies. The personas are evidence-based and reflect diverse motivations and barriers to the adoption of smart healthcare technology. They have already proven useful in our work. For example, they were used in a workshop with 20 members of the SPHERE team, including researchers from different disciplines. Workshop participants were divided into mixed teams, and each team was assigned a persona to work with. Each team was asked to discuss how they would describe SPHERE as a whole, how they would describe a given type of technology, and how they would describe what happens to the data collected by the sensors. Each group then presented their persona and thoughts about effective ways to engage their persona. This activity lasted approximately 1 h 30 min, and attendees participated throughout. By presenting their persona and discussing their thoughts with the other groups, participants became aware of the complex and sometimes conflicting user profiles. For the researchers who developed the personas, the workshop provided an opportunity to ensure that key user information was appropriately communicated in the personas. We anticipate that these personas will continue to be used within the project to inform and inspire the design of healthcare technologies.

5 Conclusions

This paper presents a framework of 15 user attributes and a set of five personas, which were based on a detailed ethnographic study. They provide an insight into the diverse characteristics of potential users of smart home technologies for health and care. We argue that these tools are a useful resource for the wider ubiquitous computing community, since they capture knowledge about users in a format that can be shared among members of interdisciplinary teams. Moreover, the framework can be used by other researchers to guide user research and to construct personas using their own data. Given that data-driven personas take time to develop, we offer our personas as a tool that can be used in similar contexts to inform and inspire the design of domestic healthcare technology.

Acknowledgments This work was performed under the SPHERE-IRC, funded by the UK Engineering and Physical Sciences Research Council (EPSRC), Grant EP/K031910/1. We would like to thank the participants who took part in this study for their time and insights.

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